

General

Confidential

Secret

Introduction of

LG Chem

LUSEP (PPS Compound)



# Contents

## ▶ LG CHEM ENGINEERING PLASTICS

- ▶ Global Network
- ▶ Technical Service
- ▶ EP Product Portfolio
- ▶ LUSEP Portfolio
- ▶ Applications of LUSEP
- ▶ Technical Datasheet

## ▶ CHARACTERISTICS OF LUSEP

- ▶ Long Term Heat Aging
- ▶ Chemicals and Hot Water Resistance
- ▶ Thermal Shock Resistance
- ▶ Abrasion Resistance
- ▶ Low Flash PPS
- ▶ Mold Releasing
- ▶ Thermally Conductive PPS (LUCON)

## ▶ INJECTION MOLDING GUIDE OF LUSEP

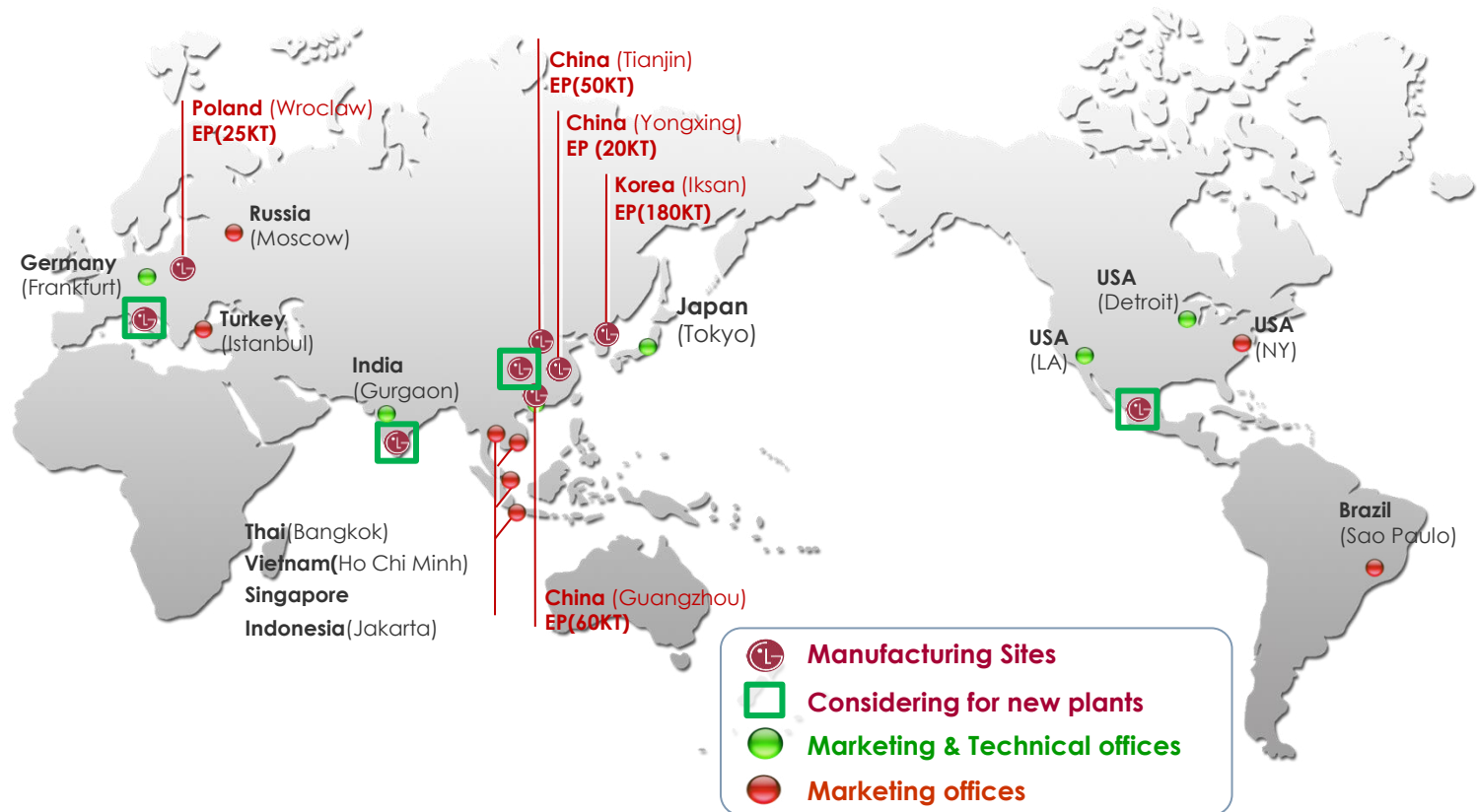
# LG Chem EP: Global Network

LG Chem's global presence can support customers by on-site supply & technical service.  
LG Chem EP will be a top supplier by continuous expansion in production sites & capacity.

**Global Network :  
On-site Production,  
Technical Service**

**Reliable Quality :  
Total Technical Service**

**Customer Oriented R&D :  
Wide Range of Product  
Portfolio**



# LG Chem EP: Technical Service

LG Chem's advanced analysis techniques and well-equipped devices enable full technical support for customers.

Global Network :  
On-site Production,  
Technical Service

Reliable Quality :  
Total Technical Service

Customer Oriented R&D :  
Wide Range of Product  
Portfolio

## Structural Analysis / Impact & Crash Design

Thermal shock analysis of EGR motor      Thermal analysis of LED bulb



## Material Properties

Fatigue property

Creep resistance

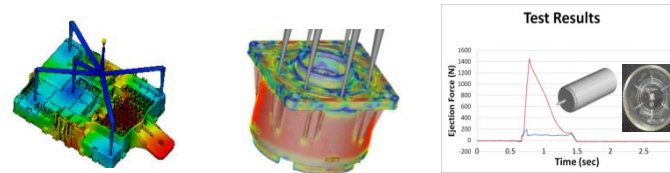


## Injection Molding Analysis

Optimization of  
gate & runner

Orientation  
of fiber

Evaluation of mold  
releasing property



## Product Reliability

Falling weight impact tester

Residual stress  
measurement



# LG Chem EP: Product Portfolio

LG Chem offers a wide range of EP products to meet customers' various needs.

Global Network :  
On-site Production,  
Technical Service

Reliable Quality :  
Total Technical Service

Customer Oriented R&D :  
Wide Range of Product  
Portfolio

Polycarbonate

Polyester

Polyamide

TPE

Olefin

mPPE

Styrenics

Acetal

Super EP

Conductive Resin

PC

PC Compound, PC Alloy

PBT, PBT Compound, PBT Alloy  
PBT/Styrenics Alloy

PA Compound, PA Alloy

TPEE (Ester Type Elastomer)  
TPO (Olefin Type Elastomer)

PP Compound

PPE/HIPS, PPE/PA Alloy

Reinforced ABS & SAN

POM, POM Compound

PPS & PPA Compound

ABS, PS, PC, mPPE, PPS Compound

LUPOY

LUPOX  
LUMAX

LUMID

KEYFLEX BT  
KEYFLEX TO

LUPOL

LUMILOY

LUPOS

LUCEL

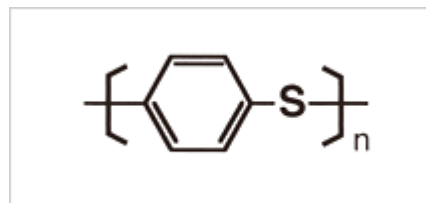
LUSEP

LUCON

# LG Chem PPS: What is PPS?

## ► Features of LUSEP

- Chemical Structure of Polyphenylene Sulfide



- ◆ LUSEP covers wide range of products to meet the various applications including automotives, electricals, electronics and industrials.
- ◆ LUSEP exhibits excellent heat resistance, chemical resistance, flame retardance and low moisture absorption.  
LUSEP therefore shows minimal decrease of mechanical strength and dimensional change by absorption of moisture
- ◆ Glass fiber reinforced LUSEP grades show superior mechanical strength and stiffness.
- ◆ Glass fiber and mineral filler reinforced LUSEP have many advantages including great dimensional stability, low coefficient of thermal expansion, low warpage and good electrical properties such as high CTI and arc resistance.
- ◆ LUSEP covers wide range of specialty grades including thermal shock resistance, abrasion resistance, low flash, and metal and epoxy adhesion properties.
- ◆ LUSEP has excellent melt flow, it is therefore possible for injection molding of small precision parts and shows good surface finish.
- ◆ LUSEP normally releases small amount of outgas caused by volatile organic compounds.



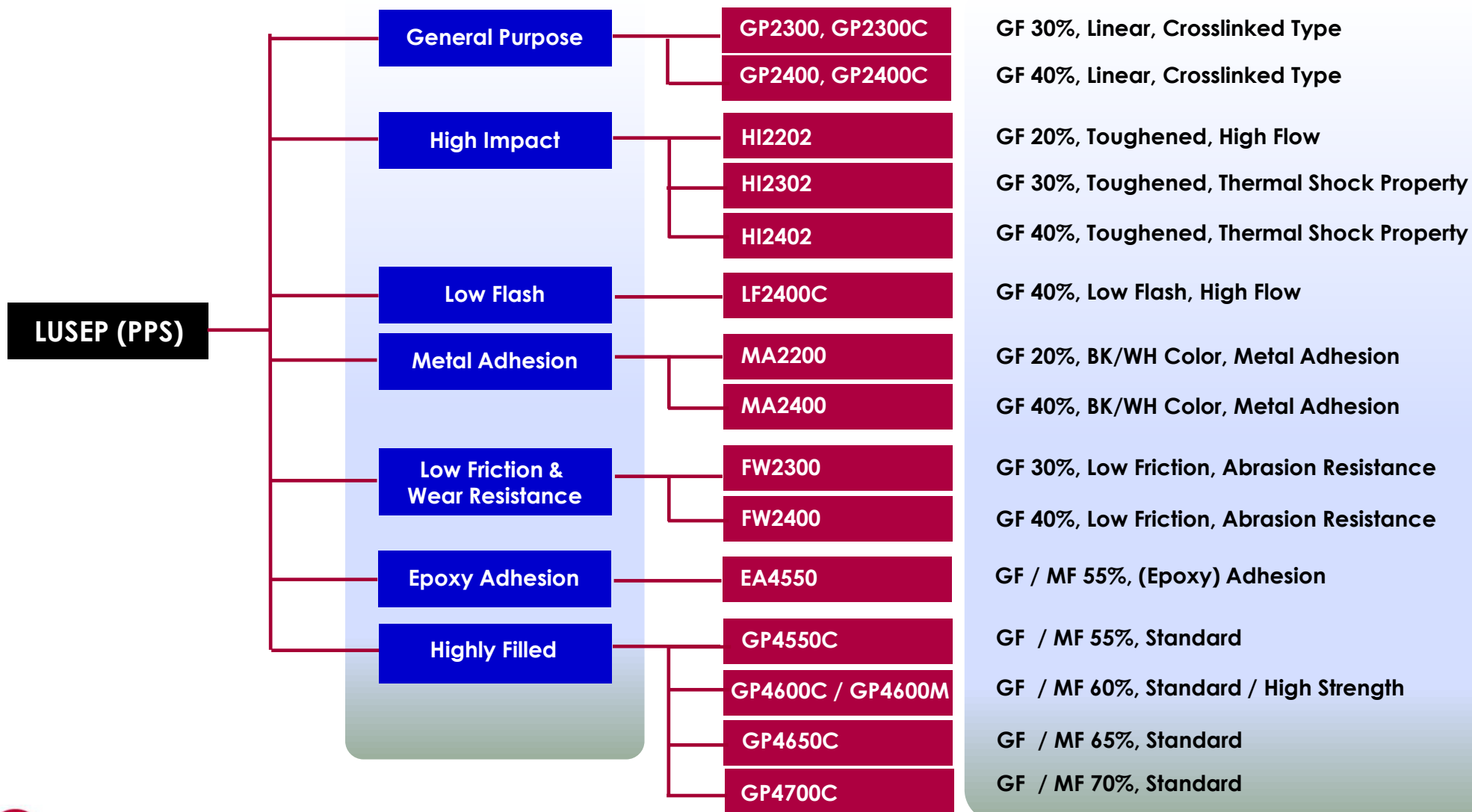
# LG Chem PPS: Opportunity of Metal and Thermoset Replacement

## ► Comparison with Competitive Materials

Criteria		Unit	PPS/GF 40%	Al-Die Casting	Phenolic Resin	Merits of PPS
Specific Gravity		-	1.66	2.71	1.76	Lower weight
Tensile Strength		MPa	180	240	70	Higher than Phenol
Flexural Strength		MPa	260	-	140	Higher than Phenol
Impact Strength		-	High	High	Low	Higher than Phenol
High Temp. Performance		-	Good	Good	Annealing required	Better than Phenol
Chemical Resistance		-	Excellent	Painting required for anti-corroison	Excellent	Painting for anti-corrosion unnecessary
Design Freedom			High	Low	Low	Higher than Phenol
Surface Finish Secondary Processing		-	Good Unnecessary	Trimming & machining required	Good Trimming required	Good Unnecessary
Mold ing	Molding Time	Sec	20 ~ 25	10 ~ 60	30 ~ 40	Shorter than Phenol
	Defect Rate	-	Low	High	High	Low
	Mold Life	Shot	0.5 ~ 1 X 10 <sup>6</sup>	0.1 X 10 <sup>6</sup>	0.3 ~ 0.5 X 10 <sup>6</sup>	2-5 times than ALDC
	Recycle	-	Possible	Regrinding impossible	Impossible	Possible

\* PPS has advantages of lower weight and manufacturing cost than aluminum and higher productivity and recyclability compared with Phenolic resin.

# LG Chem PPS: Product Portfolio

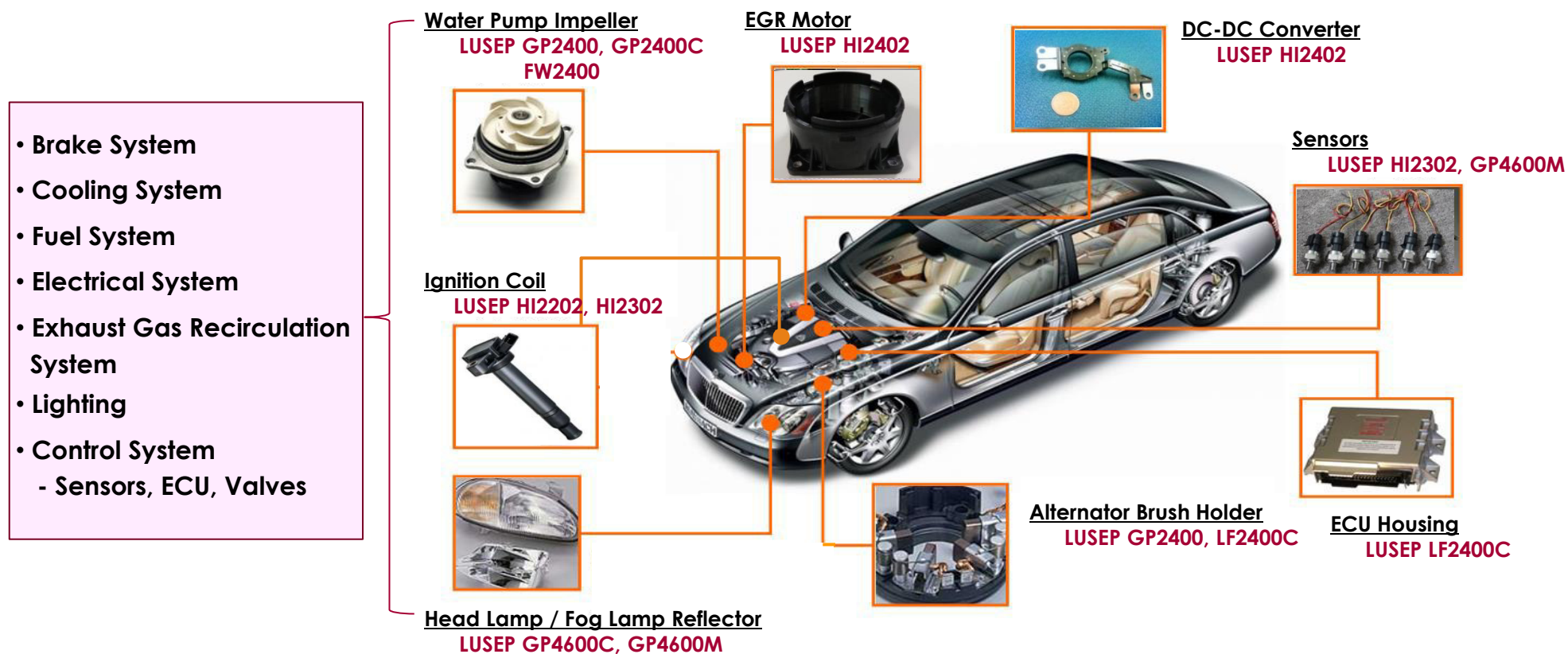




# LG Chem PPS: Grade Recommendation

## ► Automotive Electric Parts

LUSEP has excellent mechanical strength, long term heat resistance, chemical resistance, dimensional stability and electrical properties to endure for automotive underhood applications which lie under harsh environments such as high temperature, vibrations and broad range of fluids such as fuels, oils and coolants.



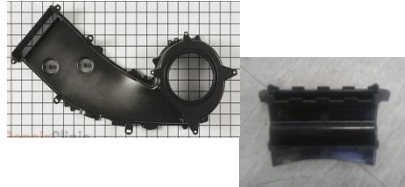
# LG Chem PPS: Grade Recommendation

## ► Electrics/Electronics and Home Appliance Parts

LUSEP has excellent properties to make it possible for weight and cost savings for E&E and home appliance products. It has superior melt flow, low mold shrinkage, high mechanical strength and excellent long term heat aging resistance in order to deal with various applications. It also has high thermal resistance and is suitable materials for SMT. Low flash grades have been developed for precision molding of sockets and connectors. Most of LUSEP grades exhibit UL94 V-0 flame retardance.

- Capacitor
- Connector / Socket
- Relay, Switch, Circuit Breaker
- Bobbin, Coil
- Gears
- Boiler Plumbing
- Consumer Electronics Parts

Washing Machine Connector Duct  
LUSEP GP4600M, GP4700C



Temperature Sensors for Washing Machine and Refrigerator  
LUSEP GP2400, HI2402



Printer Gears  
LUSEP GP2400, FW2400



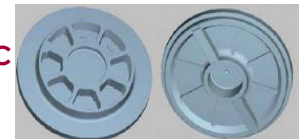
Connectors  
LUSEP GP2400, LF2400C



Fitting and Pipes for Boiler  
LUSEP HI2302, HI2202



Flow Meter Caps  
LUSEP GP4600M, GP4700C



Optical Pick-Up Base  
LUSEP GP4600M



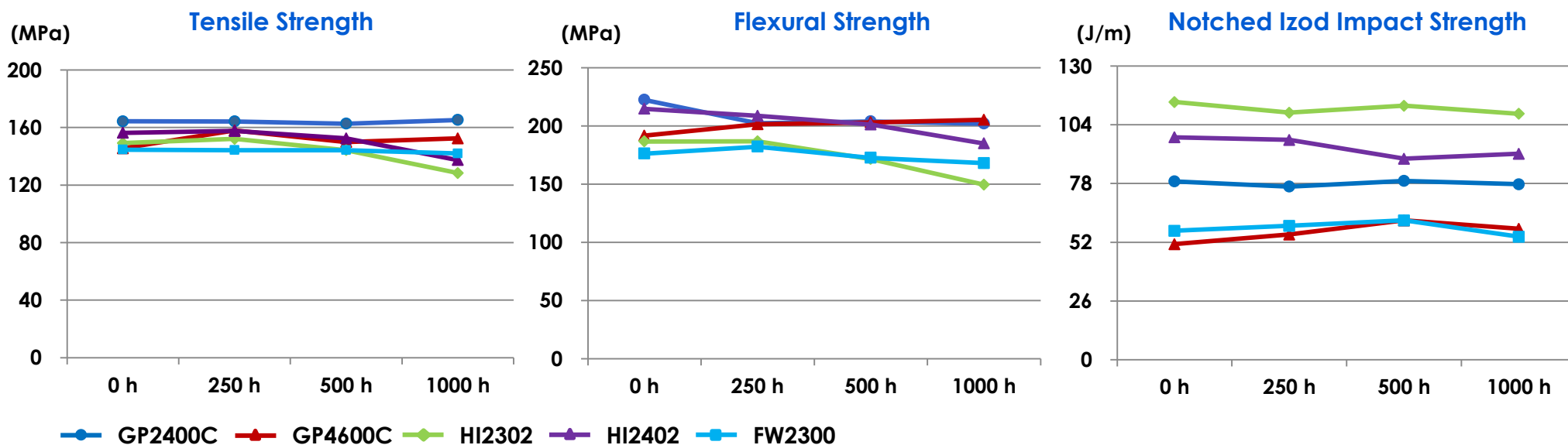
# Features of LUSEP

- ▶ Heat Aging Properties
- ▶ Chemicals and Hot Water Resistance
- ▶ Thermal Shock Resistance
- ▶ Abrasion Resistance
- ▶ Low Flash PPS
- ▶ Mold Release Characteristics
- ▶ Thermally Conductive PPS

# LG Chem PPS: Heat Aging Property

## ► Long Term Heat Aging Resistance (180°C, 1,000hrs)

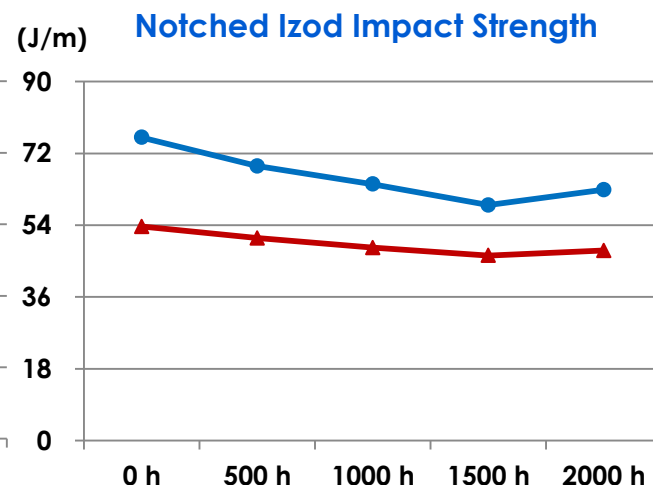
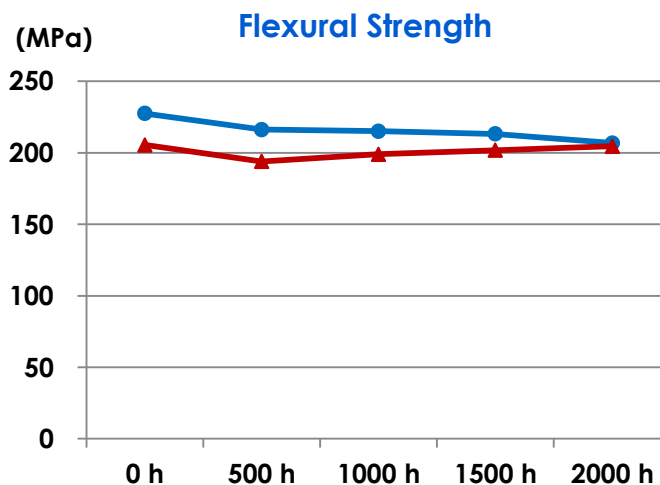
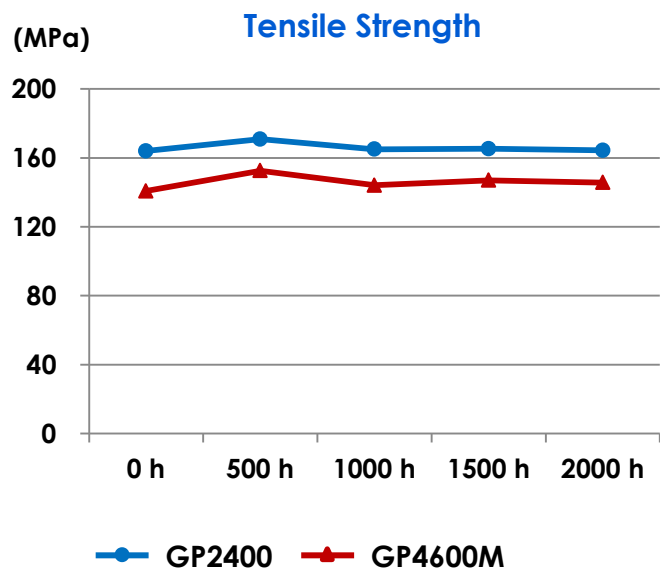
LUSEP PPS shows excellent retention of mechanical properties after prolonged exposure at elevated temperature. For most LUSEP grades, mechanical strengths are remained stable up to 1,000 hours at 180°C.



# LG Chem PPS: Heat Aging Property

## ► Long Term Heat Aging Resistance (200°C, 2,000hrs) : GP2400, GP4600M

Mechanical properties of LUSEP GP2400 and GP4600M change very little for up to 2,000 hours of heat exposure at 200°C. Mechanical strengths are retained more than 90%, and impact strengths are maintained more than 80%.



# LG Chem LUSEP: Chemicals and Hot Water Resistance

## ► Chemical Resistance of LUSEP

LUSEP PPS is crystalline thermoplastic and has superior chemical resistance for wide range of chemicals including acids, bases, hydrocarbons and organic solvents even at elevated temperatures and is not chemically dissolved below 200°C.

Solvent Resin	AROMATIC HYDRO- CARBONS		ALPHATIC HYDRO- CARBONS		HALOGEN- ATED SOLVENTS		ESTERS AND KETONES		ALCOHOLS		AMINES		STRONG ACIDS		STRONG BASES	
	25°C	93°C	25°C	93°C	25°C	93°C	25°C	93°C	25°C	93°C	25°C	93°C	25°C	93°C	25°C	93°C
Nylon	1	1	1	1	1	2	1	1	1	2	-	2	5	5	2	3
PC	5	5	1	1	5	5	5	5	-	2~5	-	5	1	1	5	5
PBT	2	5	1	3~5	3	5	2	3~4	1	1	1	1	1	1	1	1
PTFE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PPO	4	5	2	3	4	5	2	3	-	2~5	-	5	1	2	1	1
<b>LUSEP (PPS)</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>-</b>	<b>1~3</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>
POLYSULFONE	4	4	1	1	5	5	3	4	1	1	-	5	1	2	1	1

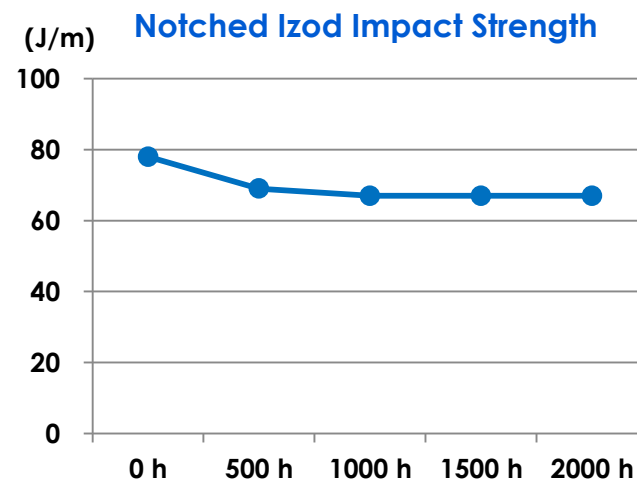
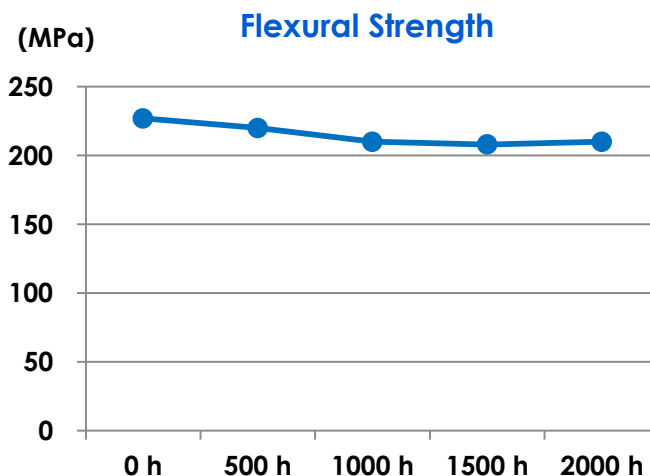
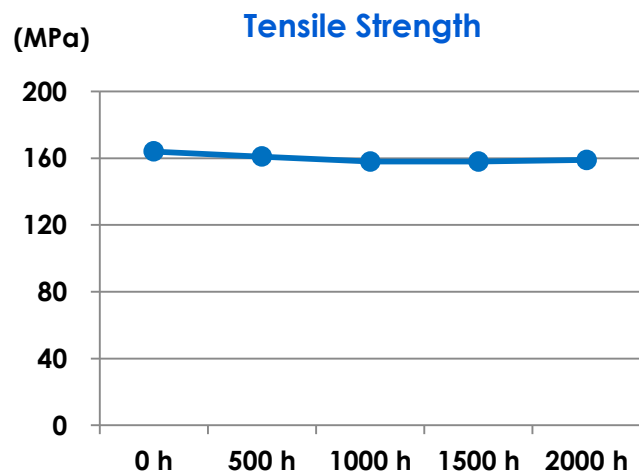
1: Very Bad Solubility, 5: Very Good Solubility



# LG Chem LUSEP: Chemicals and Hot Water Resistance

## ► Coolant Test (120°C, 2,000hrs) : GP2400

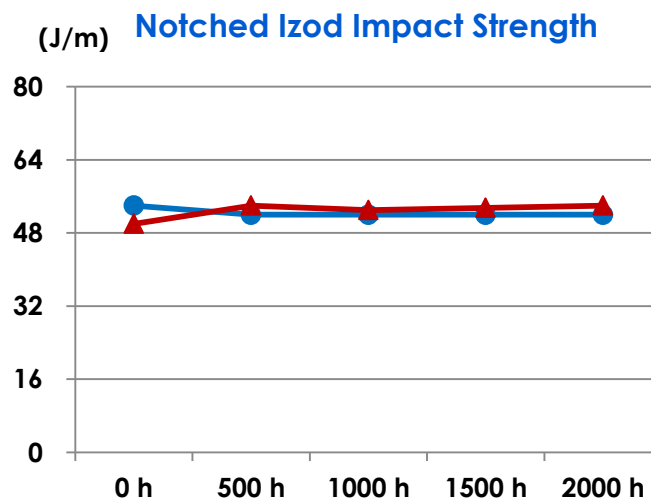
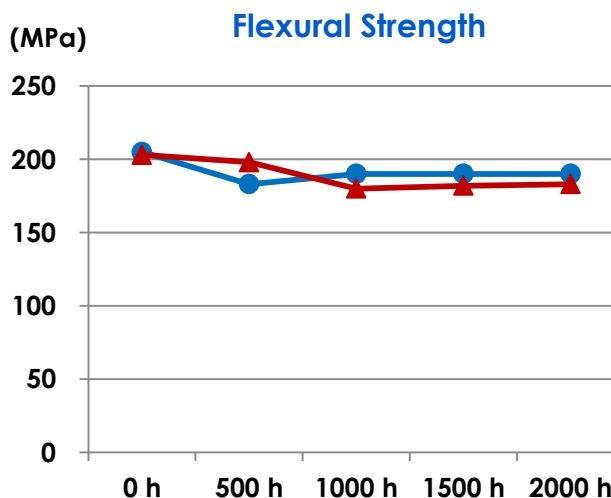
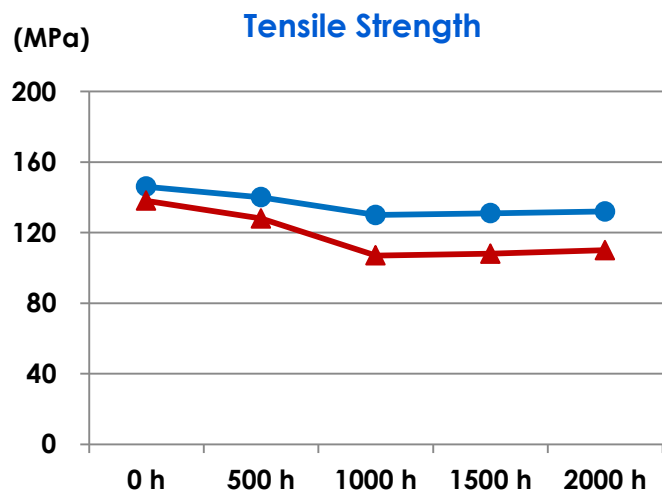
LUSEP GP2400 retains tensile and flexural strength more than 90% after 2,000 hours immersion in coolant at 120°C. The impact strength is decreased about 10% up to 500 hours and after then remained constantly.



# LG Chem LUSEP: Chemicals and Hot Water Resistance

## ► Coolant Test (120°C, 2,000hrs) : GP4600M

LUSEP GP4600M shows equal and better property retention compared with competitor's equivalent product for soaking in coolant at 120°C.

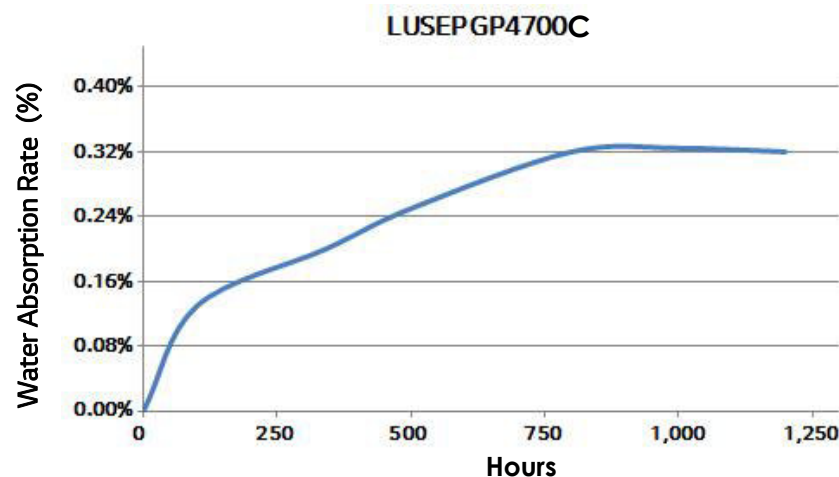
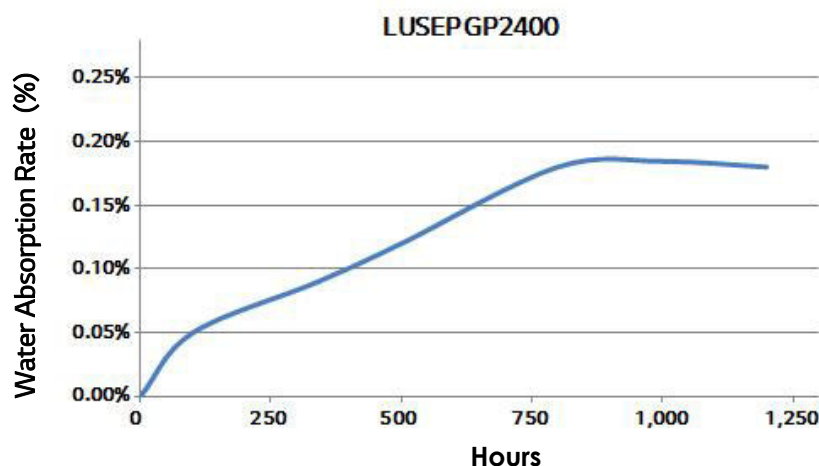


—●— GP4600M —▲— Competitor's PPS/GF+MF 60%

# LG Chem LUSEP: Chemicals and Hot Water Resistance

## ► Hot Water Resistance

LUSEP GP2400 and GP4700C exhibit very little moisture absorption rate and tend to show saturated water absorption after 875 hours of 85°C hot water treatment. Reductions in the mechanical properties are small.



• Test condition : Water absorption rate with immersion time in hot water at 85°C

## ► Property Change before and after water immersion

Property	Test Method	Unit	LUSEP GP2400			LUSEP GP4700C		
			Before immersion	23°C	85°C	Before immersion	23°C	85°C
Tensile Strength	ASTM D638	MPa	160	159	140	135	125	100
Tensile Modulus			1,450	1,410	1,320	2,250	2,200	2,040

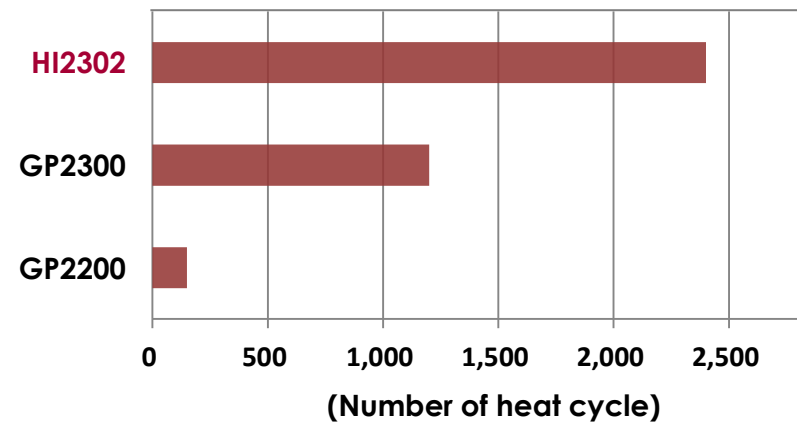
# LG Chem LUSEP: Thermal Shock Property

## ► Thermal Shock Resistance

Heat cycle tests are carried out by using small metal block inserted specimen. Thermal shock resistance of LUSEP HI2000 series show much better performance than those of standard glass fiber reinforced PPS.



\* Heat Cycle Condition : -40℃, 30min ↔ 140℃, 30min



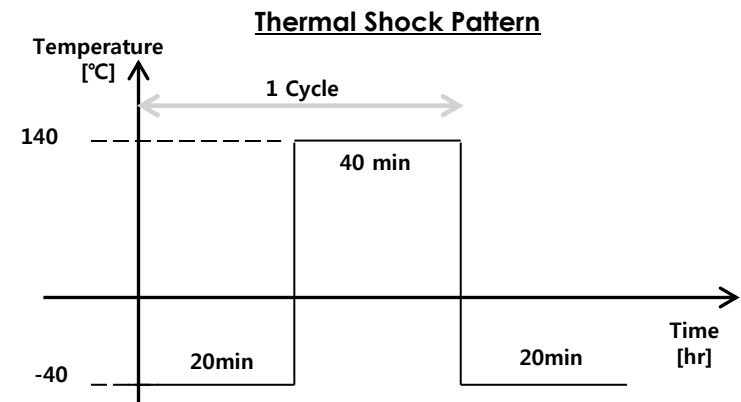
## ► Thermal Shock Evaluation of Automotive EGR\* Motor



LUSEP HI2402

Standard PPS/GF40%  
(Crack detected at 90 cycles)

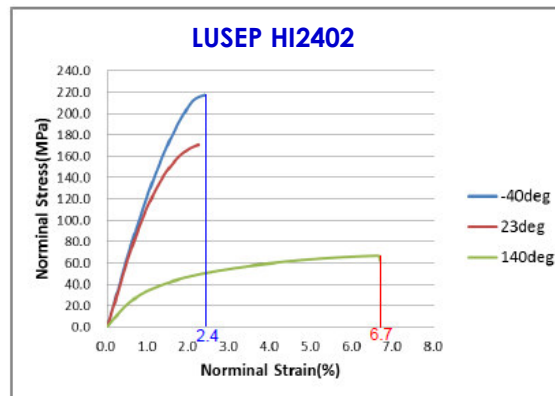
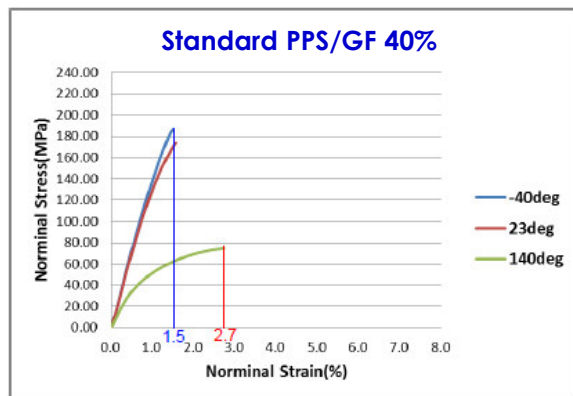
\* EGR : Exhaust Gas Recirculation



# LG Chem LUSEP: Thermal Shock Property

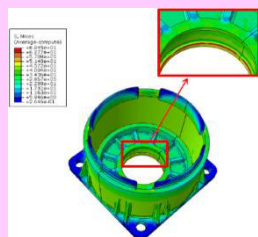
## ► Stress vs. Deformation

LUSEP HI2402 exhibits higher elongation than standard PPS+GF40% at low and elevated temperatures.



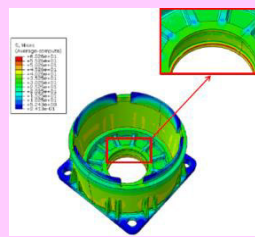
## ► Thermal Shock Analysis

LUSEP HI2402 undergoes lower stress than standard PPS+GF40% at low and elevated temperatures.

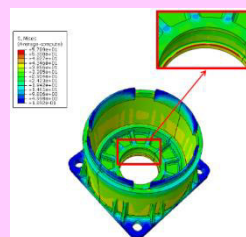


Max. Stress : 68.45MPa

T = - 40°C

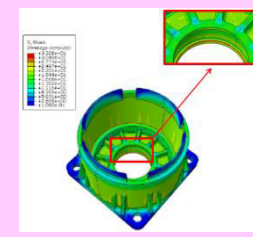


Max. Stress : 60.26MPa



Max. Stress : 57.89MPa

T = 140°C



Max. Stress : 33.26MPa

# LG Chem LUSEP: Abrasion Resistance

## ► Taber Abrasion Test Results

LUSEP FW series have superior wear resistance than standard glass fiber reinforced PPS.

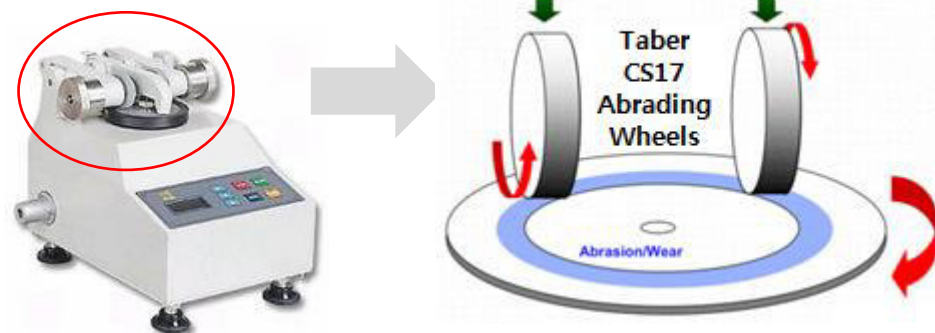
Grade	Abrasion (mg)	Feature
LUSEP GP2300	130	Standard, G/F 30%
LUSEP GP2400	150	Standard, G/F 40%
LUSEP FW2300	80	Wear resistance, G/F 30%
LUSEP FW2400	95	Wear resistance, G/F 40%

\* Test Condition: 1kg Load, 3,000 Cycles

## ► Coefficient of Friction (vs. Steel, 1kg Load)

Grade	Coefficient of Friction	Feature
LUSEP GP2300	0.08	Standard, G/F 30%
LUSEP GP2400	0.09	Standard, G/F 40%
LUSEP FW2300	0.04	Wear resistance, G/F 30%
LUSEP FW2400	0.05	Wear resistance, G/F 40%

### ◆ Taber Abrasion Tester



### ◆ Measuring Coefficient of Friction Equipment



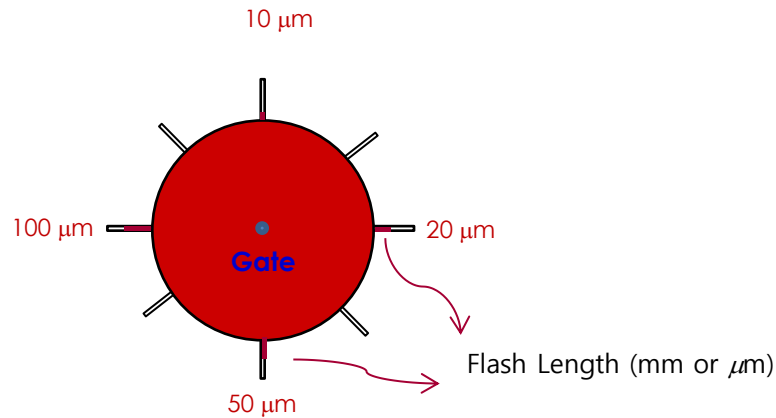


# LG Chem LUSEP: Flash Formation

## ► Evaluation of Flash Length

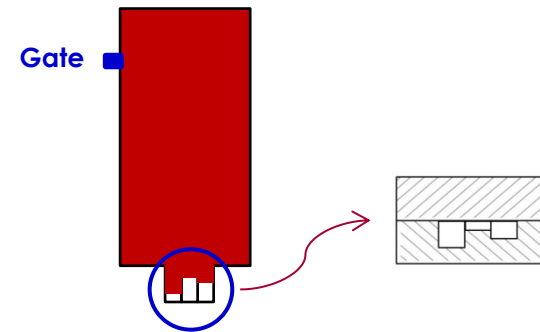
### 1) Disk mold with center pin gate

- Gas vents with different clearance are installed radially in the mold



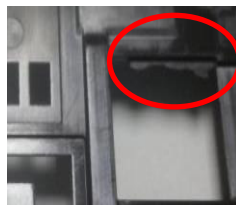
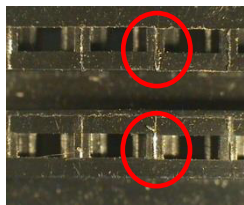
### 2) Bar type mold with side pin gate

- Gas vents with different clearance are installed at the opposite side of gate



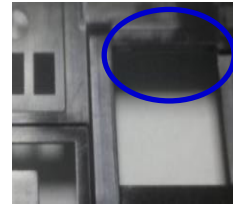
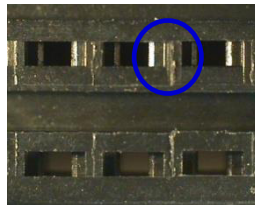
## ► Visual Examination of Microflash

Standard PPS/GF 40%



○ Microflash

LUSEP LF2400C

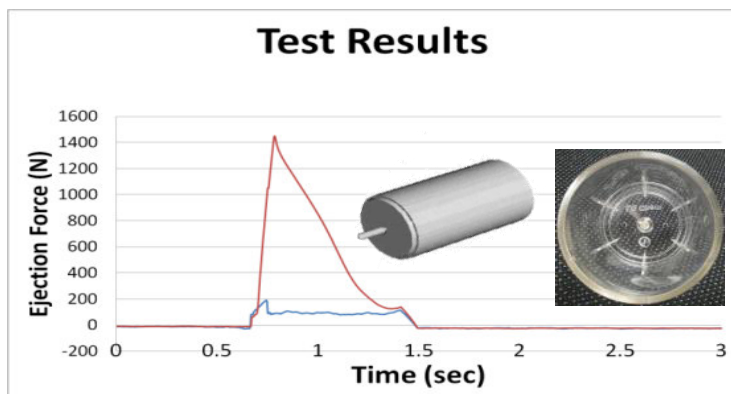


○ No microflash

# LG Chem LUSEP: Mold Release Property

## ► Evaluation of Ejection Force

- Ejection force is measured in real time through pressure sensors inserted in the ejection pins using a cup shaped mold.



## ● Result

Ejection Force (N)	LUSEP LF2400C	Competitor's PPS+GF40%
Average	500	1,600
Maximum value	710	1,650
Minimum value	430	1,575

• Injection molding conditions : Temperature = 295℃, Mold temperature = 130℃, Cooling time = 20 sec

# LG Chem LUCON: Thermally Conductive PPS

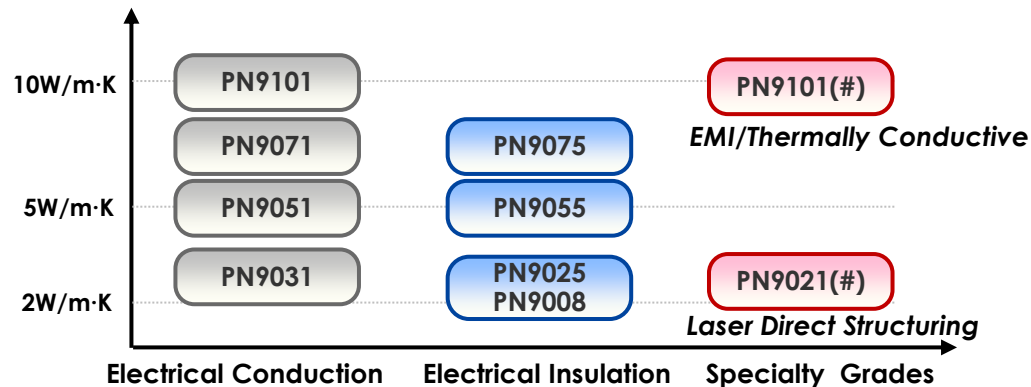
- **LUCON PN9000 Series** are thermally conductive PPS compounds and the thermal conductivity range from 2 to 10W/m.K. They have good melt flow, high heat resistance and flame retardant characteristics.

## ● Applications

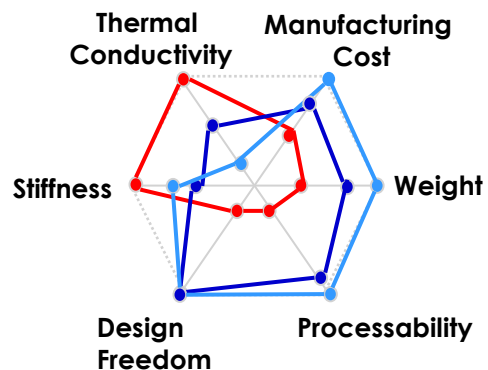
- LED Lamp Heat Sink, Housing, and Reflector
- Thermal Resistor, Heat Exchanger, Industrial Parts



## ● Product Portfolio

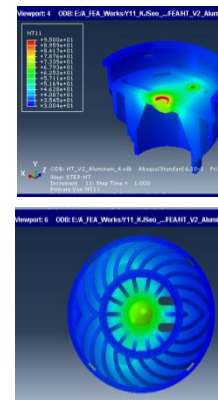


## ● Features

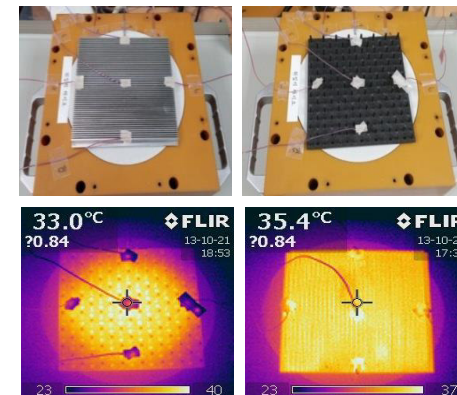


## ● Thermal Analysis

### Thermal Analysis of LED Heat Sink



### Experimental Validation (AI & LUCON)



LUSEP

# Injection Molding Guide

► Injection Molding Guide

# LG Chem LUSEP: Injection Molding Guide

## ► Injection Molding

### ● Pre-drying

- 3 ~ 5 hours drying at 120 ~140 °C is recommended.  
Color may be changed by excessive drying temperature and/or time.

### ● Cylinder Temperature

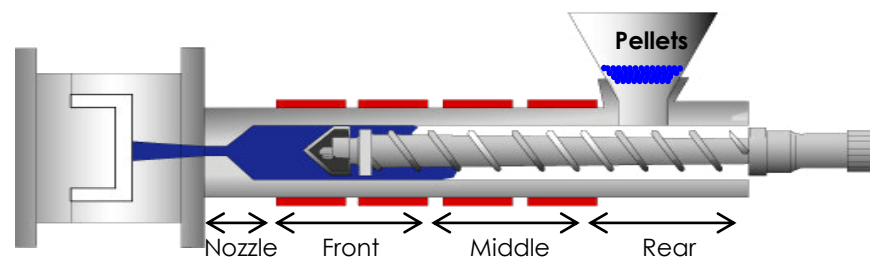
- 290 ~ 330 °C is normally recommended.

### ● Mold Temperature

- Mold temperature affects the crystallinity, surface finish and dimensional accuracy of the molded product.
- To obtain high levels of crystallinity in PPS parts, it's recommended to utilize hot mold conditions, greater than 125°C or higher up to 150°C. The advantages of high crystallinity include improved dimensional stability, increased heat deflection temperature and improved mechanical properties at elevated temperatures.

Parts molded at mold temperatures below 120 °C achieve low levels of crystallinity. If the mold temperature is near the glass transition temperature, 80°C to 100 °C, of PPS, undesirable appearance quality and mold release failure are likely to occur.

Processing Parameter		Unit	Range
Cylinder Temperature	Nozzle	°C	300 ~ 330
	Front	°C	290 ~ 320
	Middle	°C	290 ~ 320
	Rear	°C	280 ~ 300
Pressure Condition	Injection Pressure	MPa	70 ~ 150
	Holding Pressure	MPa	30 ~ 70
	Back Pressure	MPa	1 ~ 10
Mold Temperature		°C	120 ~ 150
Drying Condition		°C Hr	120 ~ 140 3 ~ 5



# LG Chem LUSEP: Injection Molding Guide

## ► Mold Design and Materials

- Recommendations for mold design
  - Gas vent should be installed at the flow ends.
  - Valve gates are recommended to reduce drool.
  - Sufficient draft angle is required to eject the part without bending or failure.
  - Due to the high mold temperature of LUSEP, tolerance by thermal expansion should be considered.
- Recommendations for mold material
  - It is recommended to use corrosion-resistant material for LUSEP mold.
  - Because of the abrasive nature of the glass fiber and mineral fillers incorporated in LUSEP PPS compounds, hard tool steels with good wear resistance are required for mold cores and cavities.
- Table : Features of recommended mold materials

Mold Material (Hard Tool Steel)	Hardness (HRC)	Wear Resistance	Surface roughness	Strength	Machinability
KP4M	34	B	C	C	C
NAK80	40	B	A	B	D
ASSAB718	33	C	A	C	C
STAVAX	45	B	A	B	C
SKD11	55	C	C	A	C

\* A : Excellent, B : Good, C : Poor



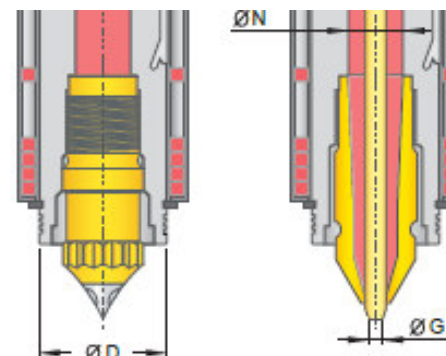
# LG Chem LUSEP: Injection Molding Guide

## ► Hot Runner Guide

- In the case of using hot runner for injection molding of LUSEP PPS, temperature of hot runner should be set to the front zone cylinder temperature of injection molding machine. Gate depends on the type, specifications and locations of heaters and sensors. In general, gate temperature should be set 10 ~ 20°C higher (320 ~ 350°C) than those of hot runner to prevent solidification of PPS resin at the nozzle tip.
- ※ Since set temperature depends on the injection molding machine, mold and gate type, it is also important to confirm the solidification temperature of resin under real environment.
- For highly filled LUSEP grades, proper selection of hot runner and size and material of gate is important above all. In the case of nozzle tip, metals with higher thermal conductivity and hardness (ex: Aluminum-Bronze) than those of general Beryllium-Copper are recommended to prevent solidification and improvement of durability.

◆ Table : Recommended Specifications for Hot Runner and Gate

Category	Recommended Specification
Nozzle Outer-diameter ( $\Phi D$ )	<ul style="list-style-type: none"><li>• Below 70g/gate : <math>\Phi 25</math>mm or smaller</li><li>• Above 300g/gate : bigger than <math>\Phi 35</math> mm</li></ul>
Nozzle Inner-diameter ( $\Phi N$ )	<ul style="list-style-type: none"><li>• 20% or less reinforced : bigger than <math>\Phi 10</math> mm</li><li>• 30% or higher reinforced : bigger than <math>\Phi 15</math> mm</li></ul>
Gate Size ( $\Phi G$ )	<ul style="list-style-type: none"><li>• 20% or less reinforced : bigger than <math>\Phi 2.0</math> mm</li><li>• 30% or higher reinforced : bigger than <math>\Phi 1.5</math> mm</li></ul>
Nozzle Tip Material	<ul style="list-style-type: none"><li>• Thermal conductivity : higher than 70~80% conductivity of Copper</li><li>• Hardness : higher than 30HRC</li></ul>



- ※ It is recommended to determine proper specifications for hot runner and nozzle considering the characteristics of molded part and filler content of PPS resin.